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Injury to Seed Beans During Threshing and Processing[1]

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For some time it has been generally recognized that the threshing and processing of beans lead to injuries to some of the seeds and that many seeds thus injured do not produce normal seedlings. Apparently the first published discussion of this problem was by Harter.[2] Later, Borthwick,[3] Bainer and Borthwick,[4] and Goss [5] published observations on the relation of threshing and processing to seed injury of lima bean. More recently the Associated Seed Growers, Inc., have published a booklet [6] discussing the relation of mechanical handling of snap bean seed to the seed's commercial value.

The rapid development of snap bean seed production in the Mountain States and the present use of small-grain combines for threshing the seed have renewed interest in the problem. Also, reports of sudden loss of viability of occasional lots of snap bean seed in storage have

[1] Investigations reported here were supported in part by Research and Marketing Act funds.

[2] Harter, L. L. thresher injury a cause of baldhead in beans. Jour. Agr. Res. 40: 371–384, illus. 1930.

[3] Borthwick, H. A. thresher injury in baby lima beans. Jour. Agr. Res. 44: 503–510, illus. 1932.

[4] Bainer, R., and Borthwick, H. A. thresher and other mechanical injury to seed beans of the lima type. Calif. Agr. Expt. Sta. Bul. 580, 30 pp., illus. 1934.

[5] Goss, W. L. germination of fordhook lima beans. Assoc. Off. of Seed Anal. No. Amer. Proc. [1935] 27: 52–55. 1936.

[6] Associated Seed Growers, Inc. a study of mechanical injury to seed beans. Asgrow Monog. No. 1, 46 pp., illus. New Haven, Conn. 1949.

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given rise to the question whether mechanical injury to the seed may have had a part in causing the loss. Accordingly, a detailed study has been made at the Plant Industry Station of mechanical injury to snap bean seed resulting from threshing and processing in relation to seed germination and seedling defect.

MATERIAL AND GENERAL METHODS

Seed produced under commercial conditions, principally in Idaho, was obtained through cooperation of some of the leading producers of seed beans.[7] In 1948 eight seed bean producers furnished samples of the following varieties from 50 fields: Stringless Black Valentine, Bountiful, Tendergreen, Topcrop, Logan, Rival, Brittle Wax, and Giant Stringless Green Pod. From most fields, samples were obtained (1) in the pod, (2) after threshing, (3) after milling, and (4) after hand-picking. In 1949 ten producers furnished samples of the Stringless Black Valentine, Bountiful, Tendergreen, Topcrop, and Logan varieties.[8] Because experimental results in 1948 showed conclusively that hand-shelled seed produced no appreciable percentage of abnormal seedlings, in 1949 hand-shelled seed was not used.

Each cooperator supplied information for each field sampled as to soil type, previous crop, weather at harvest, insect attacks, disease, and type of thresher used. The samples, except those of beans in the pod, were forwarded to the Plant Industry Station in airtight grain-sample cans.

Bean seed coming from the threshing machine contains trash, split seeds, and cracked seeds. Cleaning mills remove the trash and badly broken seeds. Next the seed is run on a slowly moving belt before operators who hand-pick it—that is, remove cracked, broken, and discolored seeds by hand. In connection with the hand-picking process the seed is elevated, passed through chutes, and dropped into bins. The samples of seed that had been threshed only and those of seed that had been threshed and milled but not hand-picked were cleaned of trash and of broken and discolored seed by hand, so that they could be tested in comparison with samples that had been hand-picked by the producers. Moisture determinations were made on all seed samples.

Seeds were germinated in 8 lots of 50 each in rolled towels at 20° to 30° C. daily alternation of temperatures and also in 4 lots of 100 each in a sterilized muck-and-sand mixture in the greenhouse. Germination percentages in rolled tests averaged 80.6; those in greenhouse tests, 82.6. Although the difference is small, it is statistically significant owing to the consistency of the data. The correlation coefficient for the percentages obtained by using the two methods is 0.94. Statements as to significance of results presented in this paper are

[7] The following seed companies contributed seed and advice: Associated Seed Growers, Inc., New Haven, Conn.; W. Atlee Burpee Co., Philadelphia, Pa.; Charter Seed Co., Twin Falls, Idaho; Corneli Seed Co., Inc., St. Louis, Mo.; Ferry-Morse Seed Co., Detroit, Mich.; Northrup, King & Co., Minneapolis, Minn.; Rogers Bros. Seed Co., Inc., Idaho Falls, Idaho; Washburn-Wilson Seed Co., Moscow, Idaho; and F. H. Woodruff & Sons, Inc., Milford, Conn.

[8] Because some cooperating companies did not grow Logan in 1949, other companies furnished samples of this variety from more than 1 field in order to have 10 samples of each variety. Because of a crop failure in 1 field, the total number of fields actually sampled was 9.

supported by statistical analyses of the data. The tables showing germination results are in all cases summaries combining laboratory and greenhouse records.

In addition to generally recognized abnormal seedlings that develop from seed injured in processing, it was found that many samples produced a high percentage of seedlings having some degree of injury but of sufficient vigor to produce seedlings having field value under favorable conditions. Seeds producing these slightly to moderately injured seedlings were included in the number counted as germinated, classified in this circular under germination (field value). Examples of such seedlings appear in figure 1.

Although most of the published discussion of abnormal bean seedlings has concerned injury resulting in "baldheads,"[9] many other types of injury were observed that, singly or in combination, prevent development of normal bean seedlings. Most of the seedlings classed as abnormal showed more than one type of injury. Some of the types of seedlings so classed are illustrated in figure 2.

Many samples contained seeds shown in the germination tests to have been internally injured to such a degree that little or no growth took place. These were recorded as "broken seeds."

SEED LOSS FROM THRESHING AND PROCESSING

Broken seeds removed by milling and by hand-picking are, of course, a total loss to the grower. This loss must be considered in addition to the reduction in quality of commercial seed shown by the germination tests. To determine the seed loss during threshing and processing, seeds discarded as cracked, broken, and discolored in hand-cleaning, as well as the cleaned seed, were weighed. The results are given in table 1. Although milling had removed much of the broken seed, it had left a considerable part to be removed by hand-picking.

TABLE 1.—*Seed removed from 1949 samples as cracked, broken, and discolored before germination tests were made (percentage by weight)*

Variety	Seed removed—		
	From threshed samples	From milled samples	Average
	Percent	*Percent*	*Percent*
Black Valentine	2. 0	1. 0	1. 5
Bountiful	8. 1	5. 9	7. 0
Tendergreen	3. 2	2. 3	2. 7
Topcrop	4. 3	1. 8	3. 1
Logan	7. 2	2. 7	4. 9
All varieties	5. 0	2. 7	----------

[9] "Baldhead" is the term generally applied to a bean seedling in which the plumule fails to develop.

FIGURE 1.—Seedlings showing effects of slight to moderate mechanical injury of seed: *A*, Normal seedling with no mechanical injury visible; *B*, lesion on hypocotyl; *C*, one primary leaf off; *D*, lesion at cotyledon line; *E*, no primary root, vigorous secondary growth; *F*, severe injury at cotyledon line; *G*, injury at primary-leaf level.

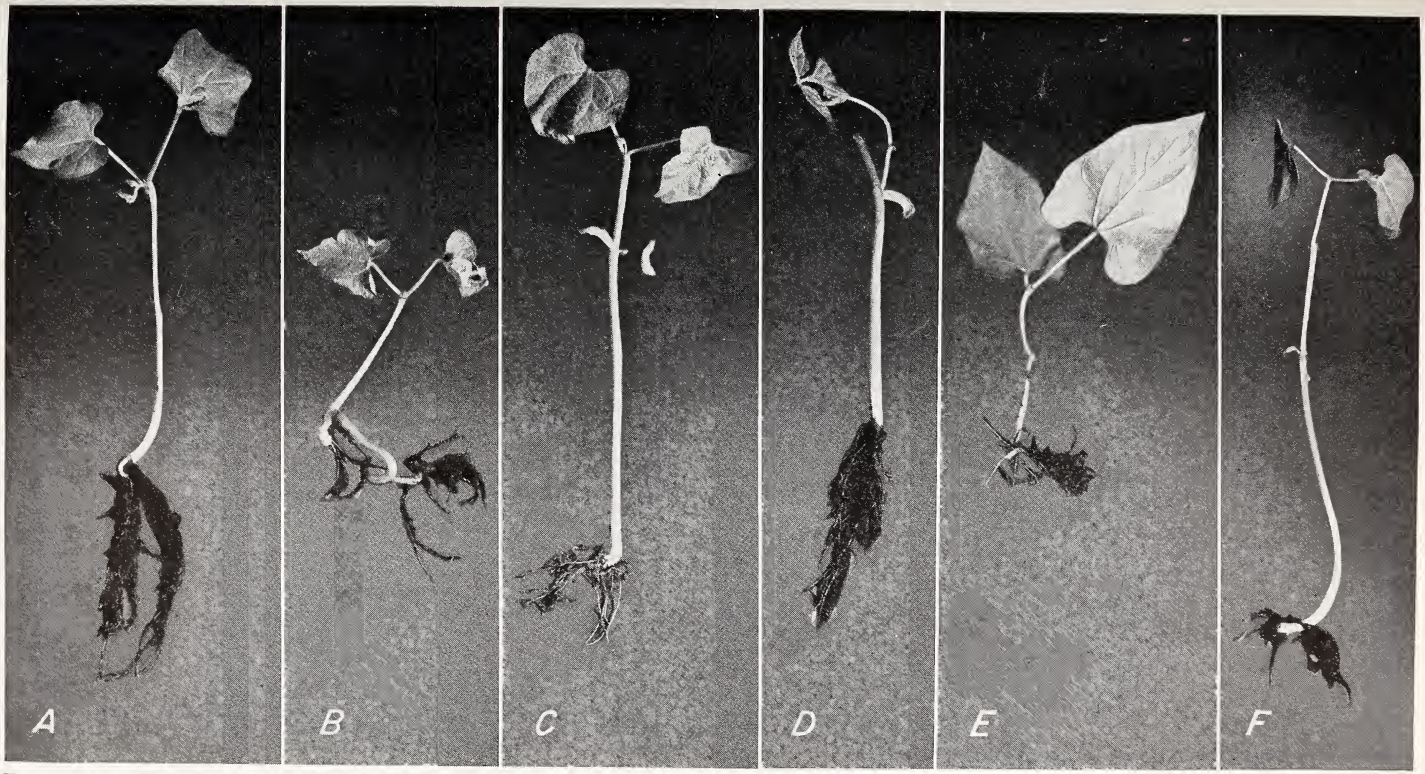


FIGURE 2.—Seedlings showing marked abnormality resulting from mechanical injury of the seed: *A*, No primary root, few secondary roots and slight injury at primary-leaf level; *B*, no development of primary bud and severe break to hypocotyl and root region; *C*, severe injury at primary-leaf level affecting development of primary bud and no primary root with scant secondary roots; *D*, baldhead with development of axillary bud; *E*, no development of bud above primary leaves, injury at cotyledon line, and no primary root; *F*, no development of bud above primary leaves, injury to first internode, and no primary root. Such seedings were not included in germination counts.

To find what percentage of the obviously injured seeds that were removed in the cleaning operation would have germinated if planted, germination tests were made with damaged seeds and seed pieces amounting to more than half a seed each. Lots of 100 seeds each were used. From 11 to 40 percent of the seeds germinated, and from 2 to 10 percent produced apparently uninjured seedlings.

EFFECT OF THRESHING, MILLING, AND HAND-PICKING ON SEED QUALITY

Small but significant decreases of germination and increases of slightly injured seedlings were associated with milling as compared with threshing only, in both the 1948 and the 1949 tests (table 2). There was evidence of further injury in the hand-picking operation in 1948, but this was not confirmed by the 1949 results. No appreciable percentages of injured and abnormal seedlings developed from the hand-shelled seed tested in 1948; therefore nearly all the injuries and abnormalities found in seedlings produced by the threshed and processed seeds must have resulted from mechanical injury to seed during threshing and processing. The high incidence of injury in seedlings from the apparently uninjured seeds of the hand-picked samples, together with the moderate germination from obviously injured seeds mentioned under "Seed Loss From Threshing and Processing," shows that degree of injury to seed coats does not necessarily indicate degree of injury to the embryo.

TABLE 2.—*Effect of threshing, milling, and hand-picking on seed quality, as shown by germination tests*

Processing step	Means for five varieties [1]					
	Germination (field value)		Uninjured seedlings		Injured seedlings included in germination count	
	1948	1949	1948	1949	1948	1949
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hand-shelling	99. 0		98. 2		0. 8	
Threshing	84. 0	83. 0	71. 1	64. 5	12. 9	18. 5
Milling	81. 8	80. 5	66. 7	58. 8	15. 1	21. 7
Hand-picking	80. 2	80. 2	63. 1	58. 3	17. 1	21. 9
Least significant difference at 99 to 1	1. 7	1. 4	2. 8	1. 9		1. 7

[1] Data represent same varieties as those of table 1.

DIFFERENCES IN SEED QUALITY AMONG VARIETIES

In 1948 the number of samples was not the same for each variety tested and was very small for each of the newer varieties—Rival,

Topcrop, and Logan. In 1949, however, samples were available from 9 fields of Logan and 10 fields of each of the other varieties. Germination values for the 5 varieties that were used in both years are shown in table 3. In 1948 percentages of germination and of uninjured seedlings were almost the same for Tendergreen as for Topcrop and very little lower for Logan. In 1949 there were significant differences in favor of Tendergreen as compared with Topcrop and in favor of Topcrop compared with Logan. It is believed that the number of samples tested in 1949 is large enough to make these results indicative of a trend in germination value of available seed of these varieties. In both years the percentage of slightly to moderately injured seedlings was much higher for Topcrop, Logan, and Tendergreen than for Stringless Black Valentine and Bountiful.

TABLE 3.—*Occurrence of seedling injury by variety*

Variety	Means for three processes					
	Germination (field value)		Uninjured seedlings		Injured seedlings included in germination count	
	1948	1949	1948	1949	1948	1949
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Black Valentine	85. 3	90. 1	74. 7	78. 8	10. 6	11. 3
Bountiful	85. 0	85. 1	71. 3	67. 4	13. 7	17. 7
Tendergreen	79. 5	82. 3	61. 6	58. 3	17. 9	24. 0
Topcrop	79. 2	77. 8	60. 3	51. 7	18. 9	26. 1
Logan	77. 6	70. 2	59. 8	44. 8	17. 8	25. 4
Least significant difference at 99 to 1	3. 8	1. 7	6. 3	2. 5	--------	1. 9

Mean germination values for the samples of hand-picked seed, which represent seed prepared for sale, are shown in table 4. In 1949 average germination of hand-picked seed was lower for Topcrop than

TABLE 4.—*Average germination of samples of hand-picked seed of five varieties from 1948 and 1949 crops*

Variety	Germination (field value)	
	1948	1949
	Percent	*Percent*
Black Valentine	84	90
Bountiful	82	84
Tendergreen	79	81
Topcrop	77	77
Logan	75	68

for Tendergreen. For each of these varieties, germination of hand-picked seed of only one crop fell below 70 percent; and that of only two crops of Topcrop and three of Tendergreen fell below 75 percent. These results suggest that high germination in these varieties can be obtained by using special care in threshing and cleaning.

Figures on occurrence of baldheads and of other abnormal seedlings in 1949 (table 5) show that samples of Bountiful and Tendergreen produced significantly higher percentages of baldheads than those of the three other varieties. Samples of Topcrop and Logan produced high percentages of seedlings having other abnormalities. Striking differences appeared among varieties as to percentage of broken and decayed seeds that were not removed in the hand-picking process but were so injured internally that the embryo made little or no growth. The proportion of such seeds was especially high for Logan.

TABLE 5.—*Classification according to defects, by variety, of 1949 seed and seedlings considered not to have germinated*

Variety	Means for all three processes		
	Baldheads	Total abnormal seedlings	Broken and decayed seed [1]
	Percent	*Percent*	*Percent*
Black Valentine	2. 8	6. 1	3. 4
Bountiful	5. 4	9. 0	5. 8
Tendergreen	5. 4	10. 2	8. 2
Topcrop	3. 4	10. 1	12. 7
Logan	3. 3	11. 8	18. 9
Least significant difference at 99 to 1	. 6	1. 1	2. 0

[1] Based on rolled-towel tests only.

Many have commented on the high proportion of seedlings with uneven cotyledons and the comparatively high proportion with triple cotyledons in crops of the newer bean varieties. In making germination tests, records were kept of the numbers of seedlings with these characteristics. The mean percentage of seedlings having one cotyledon much larger than the other was strikingly high for Topcrop, Logan, and Rival (table 6). Occasional samples of Tendergreen and Giant Stringless Green Pod had high proportions with this characteristic. All the varieties tested had at least occasional seedlings with uneven cotyledons. The results of this study do not indicate that mechanical injury of seed is related to percentage of seedlings with uneven cotyledons. The proportion of seedlings with three cotyledons was low for all the varieties; it seemed to be higher for Topcrop than for any of the others.

TABLE 6.—*Occurrence, by variety, of seedlings with uneven cotyledons and seedlings with triple cotyledons*

Variety	Proportion of seedlings having uneven cotyledons						Mean of seedlings having 3 cotyledons, 1949
	1948			1949			
	Mean	Lowest [1]	Highest [1]	Mean	Lowest [1]	Highest [1]	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Black Valentine	0. 05	0	0. 5	0. 1	0	0. 5	0. 25
Bountiful	. 1	0	. 5	. 2	0	1. 0	. 19
Tendergreen	4. 7	. 1	11. 2	3. 7	0	15. 0	. 27
Topcrop	21. 2	6. 7	42. 2	23. 8	12. 0	37. 0	. 98
Logan	20. 6	. 8	25. 9	22. 0	6. 0	41. 0	. 20
Rival	28. 2	26. 7	29. 7	-------	-------	-------	-------
Brittle Wax	3. 8	0	4. 5	-------	-------	-------	-------
Giant Stringless	4. 2	0	27. 2	-------	-------	-------	-------

[1] Values based on 400-seed tests.

INFLUENCE OF FIELD CONDITIONS AND THRESHING METHODS

Information from cooperators as to soil type, previous crop, weather at harvest, insect attacks, and disease yielded no evidence that any of these factors was correlated with seed injury. Information as to type of thresher used indicated generally less injury from large special bean combines. Some lots threshed with small grain combines, however, showed no greater injury. For this reason, and because many other factors varied, no definite conclusions can be drawn as to influence of type of thresher. Obviously, correct design, adjustment, and operation of combine threshers are important in avoidance of injury to seed. When samples of the same 4 varieties received from 10 producers in 1949 were tested, 1 producer's samples averaged significantly higher in germination and lower in percentage of slightly injured seedlings than those of any other. This suggests that mechanical injury can be appreciably reduced by special care in threshing and processing operations.

CONCLUSION

Results of a 2-year study of mechanical injury to bean seed resulting from threshing and processing permit the following definite statements:

(1) Threshing in some instances caused breakage that resulted in loss of over 20 percent of the seed harvested, and in a few instances milling caused equally serious breakage.

(2) Some apparently intact seed had mechanical injuries that prevented germination or resulted in seedling abnormality, and some had less severe mechanical injuries that resulted in slight injury of seedlings but did not destroy their field value.

(3) Seed milling resulted in a distinct increase in the percentage of slightly injured seedlings and a less marked but measurable reduction in production of seedlings having field value.

(4) Commercial seed of Topcrop and Logan averaged slightly lower in germination than that of Tendergreen and distinctly lower than that of the fibrous-podded varieties Stringless Black Valentine and Bountiful.

Because the influences of many factors, such as time of harvest, weathering, resistance to impact, and moisture relations, cannot be evaluated separately in studies of commercial seed, it is believed that further progress in investigating the problem of mechanical injury to bean seed can be made only through controlled studies of specially selected samples threshed with a minimum of mechanical injury.

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